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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 93.

B. T. GALLOWAY, *Chief of Bureau.*

THE CONTROL OF APPLE BITTER-ROT.

BY

W. M. SCOTT, PATHOLOGIST.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED MARCH 14, 1906.

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The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations, Farm Management (including Grass and Forage Plant Investigations), Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly conducted as separate divisions; and also Seed and Plant Introduction and Distribution; the Arlington Experimental Farm; Investigations in the Agricultural Economy of Tropical and Subtropical Plants; Drug and Poisonous Plant Investigations; Tea Culture Investigations; the Seed Laboratory, and Dry Land Agriculture and Western Agricultural Extension.

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[Continued on page 3 of cover.]

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APPLES BADLY AFFECTED WITH BITTER-ROT ON THE SAME TWIG WITH MUMMIES OF THE PRECEDING YEAR'S CROP.

U. S. DEPARTMENT OF AGRICULTURE.

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Issued March 14, 1906.

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

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[a] Detailed to Bureau of Chemistry.
[b] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 21, 1905.

Sir: I have the honor to transmit herewith the manuscript for a bulletin entitled "The Control of Apple Bitter-Rot," by Mr. W. M. Scott. This paper was submitted by Mr. A. F. Woods, Pathologist and Physiologist of the Bureau, with a view to publication.

This Bureau has for a number of years been investigating this serious disease, which nearly every year causes great loss to apple growers. The loss some years has been estimated to be more than $10,000,000. Although many attempts have been made to control the disease by the ordinary spraying methods, the results have been unsuccessful. Mr. Scott has discovered the reason for these failures, and the results of his investigations during the present season (which has been exceedingly favorable for the development of bitter-rot) indicate that the disease can be successfully controlled at a nominal cost. It now remains, through demonstration experiments to be conducted in the various apple districts, to bring the method into general use.

I respectfully recommend that this paper be published as Bulletin No. 93 of the series of this Bureau.

The accompanying illustrations are essential to a clear understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CONTROL OF APPLE BITTER-ROT.

INTRODUCTION.

Accounts of severe losses of the apple crop of the United States caused by bitter-rot (*Glomerella rufomaculans* (Berk.) Spaulding & von Schrenk) date back to 1870, and since that time destructive outbreaks of this disease have occurred at frequent intervals with apparently increasing severity until a loss of several million dollars in a single season is not uncommon. An epidemic occurred in 1900, when it was estimated that the damage to the apple crop of the United States was $10,000,000,[a] and in 1902 the attacks of the fungus were again exceedingly severe.

Although the fungus causing this disease occurs in nearly every apple-growing State in the eastern part of the United States, severe losses from it have been confined to the southern half of the apple belt, Missouri, Illinois, Arkansas, Virginia, West Virginia, and Kentucky suffering especially in recent years.

This disease has had the attention of the Department of Agriculture for a number of years. In the Report of the Chief of the Section of Vegetable Pathology for 1887[b] appeared the first economic discussion of the disease by an American writer, followed in 1891[c] by a more extensive account of the fungus by Miss E. A. Southworth. In 1903 Messrs. von Schrenk and Spaulding,[d] of the Mississippi Valley Laboratory of the Bureau, published a general account of the bitter-rot disease with a description and life history of the fungus causing it.

In 1903 the attention of the Bureau of Plant Industry was called to an outbreak in Virginia and West Virginia, and the writer was detailed to investigate the trouble and arrange for remedial experiments. During the months of August and September (1903) a number of orchards in each of these States were visited, and it was found that, although several other good varieties were affected, the highly prized Yellow Newtown (also known as Albemarle Pippin) was, as usual, the greatest sufferer. In some cases the destruction was complete, and to

[a] Woods, A. F. Annual Reports, Department of Agriculture, 1901, p. 47.
[b] Annual Report of the Commissioner of Agriculture, 1887, pp. 348–350, Pl. III.
[c] Journal of Mycology, VI, pp. 164–173, Pl. XVI.
[d] Bul. 44, Bureau of Plant Industry, U. S. Department of Agriculture, 1903.

find as much as 50 per cent of the fruit of this variety harvested in good condition was exceptional. The Yellow Newtown growers of this section had had a similar experience with the crops of 1901 and 1899 (two and four years previous), and some were on the point of abandoning their orchards in despair, one man going so far as to cut down his trees. It seemed, therefore, especially desirable for the Bureau to determine the best methods for combating this disease and to obtain data upon which definite recommendations could be based. Accordingly a series of experiments was planned, which were carried out in the orchards of Mr. W. H. Goodwin, at Avon, Va., to whom the Department is much indebted for valuable services in facilitating the work. The work was outlined and some spraying done in the spring of 1904, but this being the "off year" it soon developed that there would be no crop of apples in that section, and the actual work reported upon in this paper was not commenced until the spring of 1905.

THE DISEASE AND ITS CAUSE.

A detailed account of the disease and the fungus causing it having appeared in a previous bulletin of this Bureau,[a] many details will be omitted in the following discussion, the attempt being made to include only those facts with special bearing on the subject of this paper.

THE DISEASED SPOTS ON THE APPLE.

The diseased spots are usually a quarter to a half inch in diameter before the fruit grower ordinarily notices them, but they first appear as very small, yellowish-brown, sometimes watery specks, frequently bordered with a ring of purple-red. The purplish margin is especially prominent on spots that are retarded by cool weather, and many late infections appear only as red or purplish specks, never developing farther on account of adverse conditions. On the other hand, the purplish coloration is likely to be entirely absent from a spot that is developing rapidly under favorable conditions. As the spot enlarges and grows older it becomes dark-brown in the center, shading off into a light watery margin. It is circular in outline, with a well-defined margin, and soon becomes sunken. (See Pl. I, and Pl. VI, fig. 1.)

When the spots are about one-half inch in diameter, fruiting pustules begin to appear in the form of small black dots slightly raised and usually arranged in concentric rings (Pl. VI, fig. 1). These pustules soon break through the skin (Pl. II, *G*), discharging pink, sticky spore masses, which are readily washed off by dews and rains. As the disease progresses, other rings of pustules appear and give forth spores in great abundance. When the pink spore masses are washed away the pustules appear as black ragged openings through the skin of

[a] Von Schrenk and Spaulding, l. c.

the apple. An apple may have only one diseased spot, but in a serious outbreak there are usually several, and it is not uncommon to see a fruit literally peppered with points of infection. During the past season the writer counted 1,200 on a single apple and estimated 1,000 on each of several others. When so numerous, these spots are at first raised, appearing as small brown blisters on the skin of the apple, and are frequently so arranged as to suggest that the points of infection had followed drops of water trickling down the sides of the apple, the specks being distributed evenly over the upper or stem end, from which the specked areas extend in strips toward the calyx end.

When a number of spots appear on a single apple, they soon coalesce, and three or four, gaining the ascendency, envelop the others and retain their circular shape, each producing its rings of fruiting pustules. Finally the entire fruit is converted into a dark-brown, shriveled, and wrinkled mummy, which may hang on the tree a year or more. (Pl. I, and Pl. VI, fig. 1.) However, the majority of the affected fruits fall to the ground before they are half rotten, and their decomposition is hastened by scavenger insects and decay fungi.

THE BITTER-ROT FUNGUS.

The bitter-rot disease is due to a fungus which has received the botanical name *Glomerella rufomaculans* (Berk.) Spaulding & von Schrenk,[a] but which has been known until recently as *Gloeosporium fructigenum* Berk.[b]

This microscopic plant, developing from a spore that has found its way to the apple, penetrates the skin in the form of a minute tube, which immediately begins to branch and grow rapidly in every direction. This mycelium absorbs its nourishment from the cells of the apple, killing them and thus producing the brown sunken spots known as bitter-rot.

The mycelium.—The diseased tissue is filled in the intercellular spaces with pale, delicate, much-branched threads of mycelium, which are septate, slightly granular, and chiefly 4 to 6 μ in diameter. (Pl. II, *4*, *a*.) Under favorable conditions the mycelium grows very rapidly, killing the fruit cells almost as fast as it enters the healthy tissue. It grows toward the center of the apple at a rate about equal to its lateral progress. After a time these threads become congregated just beneath the surface at certain points almost equidistant from the point of infection, forming stromata, which give rise to upright bundles of interwoven branches. These are the spore-bearing hyphæ,

[a] Von Schrenk and Spaulding. The Bitter-Rot of Apples, Bul. 44, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 29. Saccardo (Annales Mycologici, 2, p. 198) thinks the name should be *Glomerella fructigena* (Clinton) Sacc.

[b] Berkeley, M. J. *Gloeosporium fructigenum*, n. s., Gardeners' Chronicle, 1856, p. 245.

which rupture the skin and give forth pink masses of conidia, or summer spores. (See Pl. II, *6*.)

Summer spores. It is thought to be chiefly by means of summer spores that this fungus is propagated and disseminated, and countless millions of them may be produced from one rotton spot. They are produced one after another by abstriction from the ends of the fruiting branches of the fungus, and, as previously explained, exude through the ruptured skin of the apple in pink, sticky masses easily visible to the naked eye. They are readily washed off by the action of dew and rain, but upon drying become hard and glued to the skin of the apple.

A microscopic examination shows these spores to be oblong, almost cylindrical, one-celled bodies with a delicate pale-green color and granular contents. They vary in size, as also in shape, but normally measure 4–5×10–15 μ. (Pl. II, *4*, *a*.)

Ascospores.—In addition to the conidia, or summer spores, which are produced so rapidly and in such great numbers, another type of spore is produced on the old rotten apples in the autumn and probably also the following spring. These ascospores, measuring about 5×20 μ (Pl. II, *2*), are scarcely distinguishable from the summer spores, but are usually slightly curved and are borne in little sacs containing 8 spores each. These sacs, or asci (Pl. II, *1*), are produced inside of little brownish spore cases (perithecia) embedded in black nodules of mycelium on the surface of the rotten apple or mummy. This constitutes the mature stage of the bitter-rot fungus as first discovered by Clinton,[a] and is probably a means of carrying the fungus over winter and starting infection the following spring. Von Schrenk and Spaulding[b] found it on limb cankers as well as in artificial cultures. The writer secured this stage of the fungus on a number of artificially infected apples in the laboratory about three weeks after inoculation, and it developed on a few rotten apples brought in from the orchard and placed in a moist chamber. It also developed abundantly in artificial cultures on sterilized potato and nutrient agar within six weeks after inoculation.

Germination of the spores.—Placed in a drop of water under a microscope, both conidia and ascospores may be seen to germinate within three or four hours, each spore throwing out one or two, sometimes three, germ tubes. (Pl. II, *3* and *5*.) During germination a cross septum usually develops in the center of the spore, which soon becomes emptied of its contents. These germ tubes grow very rapidly, reaching several times the length of the spore within an hour after germination, and then begin branching.

There is some question as to how the threads from the germinating

[a] Clinton, G. P. Apple Rots in Illinois, Bul. 69, Ill. Agr. Exp. Sta., 1902, pp. 206–211, Pl. J.

[b] Bul. 44, Bureau of Plant Industry, U. S. Department of Agriculture, 1903.

spore find their way through the skin of the apple. The most common belief expressed by writers upon this subject is that the fungus enters through insect punctures or some other abrasion of the skin, and it has also been suggested that the fungus could probably enter through the unbroken skin. The writer's observations would indicate that a wound is not at all necessary for successful infection and that the fungus most commonly penetrates the skin. Several hundred points of infection were examined without finding any indication of a previous puncture. A large percentage of the apples on the untreated trees used as checks in the spraying experiment had from one hundred to a thousand points of infection, and in many cases the spots were so thick that when only one-sixteenth of an inch in diameter they overlapped. In the laboratory, infections were easily made by dropping water containing spores on the unbroken skin of an apple in a moist chamber.

BITTER-ROT CANKERS ON THE BRANCHES.

In 1902 it was discovered by Mr. R. H. Simpson, of Illinois, that limb cankers were associated with outbreaks of bitter-rot. Messrs. Burrill and Blair[a], of the Illinois Agricultural Experiment Station, and Messrs. von Schrenk and Spaulding[b], of the Mississippi Valley Laboratory of the Bureau of Plant Industry, working independently, soon established the relationship of these cankers to the disease on the fruit and proved by inoculation tests that these cankers were caused by the same fungus that attacks the fruit.

In describing this form, von Schrenk and Spaulding[c] state that "The cankers found on apple trees in Illinois appear as blackened depressions on apple limbs of various sizes, from last year's fruit spurs to limbs 3 to 4 inches in diameter. Thus far the cankers have not been found on the main trunk. On these limbs rounded or oblong sooty-black sunken spots occur from one to several inches long, which have more or less ragged edges." Limb cankers occur abundantly in the Virginia orchards, but the writer has so far been unable to find the bitter-rot fungus associated with any of them. However, limbs of young apple trees on the grounds of the United States Department of Agriculture inoculated with bitter-rot spores rapidly developed these cankers.

SOURCE OF INFECTION AND SPREAD OF THE DISEASE.

The question as to the chief source of the first infection each year has not been satisfactorily settled, nor is it definitely known how the

[a] Circ. 58, Ill. Agr. Exp. Sta., July, 1902, and Bul. 77, Ill. Agr. Exp. Sta., 1902, pp. 355–357.

[b] Bul. 44, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1903, pp. 29–36.

[c] L. c., p. 31.

fungus is spread from tree to tree and from orchard to orchard. It seems, however, that the mummied fruit and the limb cankers are both instrumental in carrying the fungus over winter and starting the annual infection, and that insects play an important rôle in the spread of the spores.

During the season of 1903 and again in 1905 the writer visited a number of infected orchards in Virginia and West Virginia, making special observations upon this problem. The results lead to the conclusion that the overwintering mummies hanging on the trees constitute the chief source of infection, at least in this particular region. In the majority of cases examined a mummy could be found in the upper portion of the infected area, but in no case was there found associated with such outbreaks any cankers that could be identified as bitter-rot cankers. However, from observations made in the Middle West, Burrill and Blair[a] and von Schrenk and Spaulding[b] conclude that the canker is the chief source of early infection, the fungus being held over winter in the diseased limbs and producing spores for the infection of the new crop of apples. Hasselbring[c] demonstrated that the fungus of bitter-rot remains alive over winter in the mummied apples. It seems possible that the mature spore form of the fungus discovered by Clinton may develop the following spring in the mummied fruits, starting the infection on the new crop.

After one apple on a tree becomes diseased and begins to produce spores, further infections may readily take place through the medium of raindrops which splash the spores to adjacent fruits, and heavy dews may wash the spores to the apples below. Insects are also undoubtedly instrumental in disseminating the disease,[d] and they are possibly the chief carriers of the spores from tree to tree. On the other hand the rapidity with which the disease frequently spreads over an orchard, practically destroying the entire crop within a few days, suggests the idea that the spores are carried on the wind, and indeed they seem to be omnipresent in the bitter-rot districts, only awaiting suitable weather conditions. But the spore masses being sticky when wet and glued to the skin of the apple when dry, there seems to be little or no chance for the wind to carry the spores.

INFLUENCING CONDITIONS.

WEATHER.

The predominating conditions that influence the development of bitter-rot are temperature and humidity. A few days of hot showery

[a] Bul. 77, Ill. Agr. Exp. Sta., p. 356. 1902.

[b] Bul. 44, Bureau of Plant Industry, U. S. Department of Agriculture, 1903, pp. 36–38.

[c] Burrill and Blair, l. c., p. 354.

[d] Clinton, G. C., Bul. 69, Ill. Agr. Exp. Sta., p. 197.

weather may start an epidemic that will destroy the entire crop of certain varieties, provided the fungus is present.

Moisture.—Moisture is not only necessary for the germination of the spores, but it favors the growth of the fungus and hastens spore production. In a moist atmosphere the spores are produced much more rapidly than when the air is dry. Moreover, rain is an active agent in the spread of the disease, splashing the spores from an affected apple to adjacent healthy fruits. Heavy dews followed by hot cloudy days with a humid atmosphere appear to make ideal conditions for the rapid development of this disease.

Temperature.—The fungus causing this disease is decidedly a hot-weather fungus and rarely is a serious pest north of latitude 40° N. July, August, and September are the three bitter-rot months, and a maximum temperature near 90° F. for several days in succession, coupled with suitable moisture conditions, is necessary to start a serious outbreak. Infection of some fruits may take place as early as the middle of June,[a] but the fungus grows slowly and fruits sparingly until the warmer weather of July increases its rate of development. In Virginia, on July 10, 1905, the writer observed bitter-rot spots covering a quarter to half of the apple. One specimen was somewhat more than half involved in rot, and the numerous rings of spore masses indicated that the fungus had been fruiting abundantly for days, and the infection had doubtless taken place a couple of weeks earlier. The variety was Yellow Newtown, and the fruit was scarcely more than half grown. The proper combination of heat, moisture, and an abundance of spores may not occur until August or September, or in some seasons not at all.

The fungus is so influenced by the heat of the sun, and perhaps by the light also, that the fruit on the south side of a tree may become badly affected before the disease is noticeable on the opposite side. Stinson[b] observed this fact, and in the Virginia orchards the writer found that almost invariably the fruit on the sunny side was destroyed first, and oftentimes a portion of the crop on the north side would escape when the destruction was complete on the south side. This held true not only in the particular orchard under experimentation, but in many orchards visited during the outbreak of 1903, and during the past season as well. Moreover, it was observed that fruit on the inside lower branches well protected from the sun was less attacked and often escaped when that on exposed portions of the same tree was destroyed. Owing perhaps to exposure to the sun there was a considerably higher percentage of rotten fruit on trees partly defoliated with leaf-spot fungi than in the case of trees with full foliage. Not only is the fruit on the sunny side of the tree worse affected, but the

[a] See Burrill and Blair, Bul. 77, Ill. Agr. Exp. Sta., p. 332.

[b] Bul. 1, Missouri State Fruit Experiment Station, p. 6.

points of infection are more commonly located on the sunny side of the apple. Although infections were frequently found on the shaded side of the apple, in the majority of cases, according to the writer's observations during the past season, the rotten spots developed on the side exposed to the sun.

Cold is decidedly unfavorable to the fungus and it rarely does any damage during a cool season. An outbreak may be almost completely checked by a few days of cool weather, especially when the mean temperature remains below 70° F. Late infections that take place with the approach of cool fall weather usually remain as a brown speck encircled with a red or purplish ring. However, the fungus grows somewhat in the average fall weather, and if the temperature runs up to summer heat the picked fruit may rot considerably in piles or in barrels in the orchard. This emphasizes the desirability of rushing the fruit to cold storage or to market as soon as picked. In storage at a temperature of 35° F. the fungus does not grow, and spots previously started by inoculation develop no further after being stored at this temperature.

SUSCEPTIBILITY OF DIFFERENT VARIETIES.

There is a wide range of variation in the susceptibility of the different varieties of apples to injury from bitter-rot. In Virginia the Yellow Newtown (or Albemarle Pippin) is preeminently the most susceptible commercial variety. On the other hand, the Winesap is equally conspicuous for its resistance to the disease. When in close proximity to a badly rotting variety the Winesap may become infected, but the points of infection usually remain as mere specks, rarely growing to any size. The fungus does not seem to thrive on this variety and the production of spores is scant. The Ben Davis, although one of the most susceptible varieties in the Middle West, shows a comparatively slight tendency to rot in Virginia, rarely losing more than 25 per cent of its crop. York Imperial, the variety most extensively grown in the Valley of Virginia, is less susceptible than Ben Davis, being rarely attacked to a serious extent. The Grimes also rots very little.

From rather extensive observations made during 1903 and 1905 in Virginia and West Virginia the writer has prepared the accompanying list of varieties in the order of their susceptibility to bitter-rot. This list includes only such varieties as the writer examined in orchards where bitter-rot was found, and the data are not sufficiently extensive to be entirely reliable. Those varieties almost equally susceptible are grouped together, the first group representing those that frequently lose their entire crop, the second group those that in a bad season may be expected to lose 50 to 75 per cent of their crop, the third group those that rarely suffer more than 25 per cent loss, and the fourth

group those on which the writer has never found the disease. These groups are as follows:

1. Yellow Newtown (or Albemarle Pippin), Shackleford, Bentley, Gibbs, and Missouri.

2. Arkansas Beauty, Limbertwig, Rhode Island, York Stripe, Huntsman, Pilot, Peck, Northern Spy, Jonathan, Northwestern Greening, Fall Cheese, Stark, Green Sweet, and Nero.

3. Grimes, Ben Davis, York Imperial, Gano, Arkansas, Ivanhoe, and Winesap.

4. Coffelt, Bismarck, Pewaukee, Stuart Golden, Pryor, Salome, Scarlet Cranberry, Oliver, Roxbury, Lankford, Loy, Ralls, Crawford, Carlough, and Akin.

Mr. F. W. Faurot, of the Missouri State Fruit Experiment Station, a collaborator of the Department of Agriculture, has kindly furnished the following information relative to the susceptibility of the different varieties of apples in the State of Missouri. He has arranged the varieties in their approximate order, with the most susceptible varieties first, in four classes, which do not necessarily coincide with the four classes given above. They are as follows:

1. Willow and Huntsman.

2. Ben Davis, Gano, Ingram, Smith, Rome, York Imperial, Clayton, Nickajack, and Nixonite.

3. Lowell, Porter, and Maiden Blush.

4. Arkansas, Arkansas Black, Jonathan, Grimes, Winesap, and Gilpin.

Mr. Faurot writes concerning this list as follows:

> In some seasons, however, this third group comes next to Willow and Huntsman, for when they bitter-rot at all the whole crop usually goes, especially Lowell and Porter. The reason I put them third is because some seasons they are out of the way before bitter-rot attacks them or begins to develop with any degree of severity.
>
> The varieties given constitute about all of those that are grown commercially in south Missouri. Aside from these, however, I have observed bitter-rot on very nearly every variety of apple that I have seen growing in the State, including such varieties as the ordinary Russets, Lawver, Northern Spy, Stevenson Pippin, Baldwin, and many others that are grown only a few trees in a place. I have never seen it, however, on White Pearmain, Yellow Transparent, or Red Astrachan. This is merely my personal observation, however, and I have no doubt that it occurs on these varieties the same as on others, although I have not seen it.

REMEDIAL MEASURES.

Although bitter-rot has been known in this country as a serious apple disease for at least thirty-five years, it seems that no attempt was made to find a remedy for it until about 1888. During that year Galloway[a] planned some experiments for the control of this disease,

[a] Galloway, B. T. Sulphuret of Potassium for Bitter-Rot of the Apple. Journal of Mycology, vol. V, 1889, pp. 37–38.

which were carried out by Mr. J. W. Beach, of Batavia, Ark. Sulphuret of potassium was the fungicide used, and the results reported were somewhat encouraging. In 1889 Galloway also directed a series of experiments on the treatment of this disease in Virginia. Potassium sulphid and ammoniacal copper carbonate were used, and Mr. George G. Curtis,[a] who did the spraying, reported good results from both.

The investigations thus begun were soon followed with remedial experiments by several experiment stations workers, notably Alwood,[b] Garman,[c] Stinson,[d] and Whitten,[e] all of whom reported favorable though not entirely satisfactory results from spraying with copper compounds.

Since the severe outbreak of 1900, efforts to control this disease have been continued with renewed interest, and several papers reporting results of remedial experiments have been published. In 1901 Quaintance,[f] in writing of experiments conducted in Georgia the preceding year, stated that "the results are much in favor of four applications of Bordeaux, not only in quantity of fruit but in size and appearance, and, as developed later, in keeping quality." Some of the best results that have come to the writer's attention are those reported by Stinson in 1901.[g] One plot sprayed five times gave "59 per cent of the fruit free from bitter-rot," another sprayed four times gave "78 per cent of the fruit free from bitter-rot," while one check plot had only "1.6 per cent of the fruit free from bitter-rot" and another "14 per cent of the fruit free from bitter-rot." In 1902[h] the same writer published the results of another series of experiments showing beneficial results from spraying.

As a result of their investigation in 1902, Burrill and Blair[i] recommended a systematic search for and removal of the diseased fruits and infecting cankers or mummies, stating that "the canker and infested fruit should be removed, taking care not to distribute the infection in

[a] Curtis, George G. Treatment of Bitter-Rot of the Apple. Bul. 11, Section of Vegetable Pathology, U. S. Dept. of Agriculture, 1890, pp. 38–41.

[b] Alwood, William B. Bitter-Rot. Bul. 17, Va. Agr. Exp. Sta., 1892, pp. 61–62 and 64–65. Also Ripe-Rot, or Bitter-Rot of Apple. Bul. 40, Va. Agr. Exp. Sta., 1894, pp. 59–82.

[c] Garman, H. Bul. 44, Ky. Agr. Exp. Sta., 1893, pp. 3–24.

[d] Stinson, John T. Bitter-Rot. Bul. 26, Ark. Agr. Exp. Sta., 1894, pp. 33–34.

[e] Whitten, J. C. The Bitter-Rot. Bul. 31, Mo. Agr. Exp. Sta., 1895, pp. 3–4 and 7–15.

[f] Quaintance, A. L. Bitter-Rot of Apples. Thirteenth Annual Report, Ga. Exp. Sta., pp. 360–361 and Pl. IX.

[g] Stinson, John T. Preliminary Report on Bitter-Rot or Ripe-Rot of Apples. Bul. 1, Mo. State Fruit Exp. Sta., pp 3–21.

[h] Stinson, John T. Notes on Spraying for Bitter-Rot. Bul. 2, Mo. State Fruit Exp. Sta., pp. 3–20.

[i] Bul. 77, Ill. Agr. Exp. Sta., p. 366.

the process. This is of the utmost importance if the contagion is to be stopped." They also state that "the disease can be kept in check during the summer by repeated applications of Bordeaux mixture." In a paper read before a meeting of the Illinois State Horticultural Society, Burrill[a] reports experiments conducted in three counties of southern Illinois, showing that the disease yielded to applications of Bordeaux mixture. The results of these experiments indicate especially the importance of early spraying.

Reporting upon two years' experiments, von Schrenk and Spaulding[b] state that "to a certain extent, varying from 10 to 75 per cent, Bordeaux mixture surely does prevent the ravages of the bitter-rot." They also strongly recommend the removal of diseased fruits, mummies, and limb cankers.

THE VIRGINIA EXPERIMENTS.

The orchard of Mr. W. H. Goodwin, in which the experiments were conducted, is situated on a spur of the Blue Ridge Mountains, in Nelson County, about 5 miles south of Afton. This and the adjacent county of Albemarle have long been famous for their production of the Yellow Newtown (or Albemarle Pippin) apples, some trees of which are 100 years old and still thriving. This variety is not subject to serious injury from apple scab, nor does it suffer materially from the leaf-spot diseases, and until the advent of bitter-rot magnificent crops were secured in this section without spraying.

Mr. Goodwin's orchard has a northern exposure, with an elevation of from 1,000 feet on the lower side to about 1,250 feet at the upper side. The land is very steep, having an incline of almost forty-five degrees in some places, and an extra man with a lever is required in spraying to prevent the wagon from upsetting. The soil is dark brown, almost black, deep, and fertile, such as is known throughout that section as "pippin" soil. The stones that almost completely covered the ground have been piled up in windrows, and a deep furrow has been plowed between the tree rows in which to run the upper wheels of the spray-wagon, to avoid turning over. Above the middle of the orchard is a spring with a flow of five to eight gallons a minute, which affords an ample supply of water for spraying purposes.

The bearing orchard is composed of about 800 trees of Yellow Newtown 18 to 23 years old, 500 Winesaps 8 to 23 years old, and 200 York Imperials 8 years old. There are also a number of young trees not yet in bearing. Mr. Goodwin states that the original forest was removed and the trees planted the second year after clearing, and that, as a rule, crops of corn or tobacco were grown between the rows

[a] Burrill, T. J. Experiments in Spraying for Bitter-Rot. Trans. Ill. State Hort. Soc., 1902, 54–66.

[b] Bul. 44, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1903, pp. 38–45.

until the trees came into bearing, or about twelve to fifteen years. Then the land was usually left uncultivated. A portion of it, including the experimental block, is now in sod, having been seeded to orchard grass in 1902.

According to Mr. Goodwin, bitter-rot first appeared in this orchard to a noticeable extent in 1899, and in 1901 it did considerable damage. In 1903 the trees received three early applications of Bordeaux mixture, and on September 13 of that year the writer visited the orchard and roughly estimated the loss from bitter-rot at 40 per cent. When the crop was harvested, a few days later, Mr. Goodwin estimated the loss at about 60 per cent. Since 90 per cent of the crop was lost in some unsprayed orchards in the same neighborhood, it appeared that the treatment had some effect. In 1904 there was no crop.[a]

FIG. 1.—Plat of the block of trees used in the experiment.

THE EXPERIMENTAL TREES.

Only the Yellow Newtown variety was used in this experiment, the Winesap and York Imperial not being subject to serious loss from rot in this section. As may be seen from the accompanying plat (fig. 1), 35 trees were included in the experiment. They are 19 years old and about 25 feet high, with a spread of about 25 feet. These trees have been pruned by thinning out the conflicting branches, and have developed into the broad, low, somewhat pyramidal type naturally assumed by this variety. The block is situated below the middle of the orchard, with 23-year-old trees of the same variety on the east and a young orchard not yet in bearing on the west. Below (north side) is a block of young bearing trees of the same variety, the crop of which, not being properly sprayed, rotted badly. On the upper side is a block of young trees not yet in bearing.

[a] As a rule, apple trees in this section, especially the Yellow Newtown, bear only every other year.

THE PLAN OF THE EXPERIMENT.

Object.—This experiment was designed to determine (1) to what extent bitter-rot could be controlled by spraying with Bordeaux mixture, (2) the number of applications required, and (3) the proper time to make these applications. Owing to the influence of weather conditions upon this disease it was not expected that answers to all these questions could be obtained in a single season; but the season of 1905 was so favorable to bitter-rot, the disease appearing so early and continuing with such force throughout the season, that the results obtained are believed to be a safe guide for almost any season.

Spraying scheme.—In order to solve the questions just enumerated it was necessary to cover the entire season with a varying number of applications, using a process of elimination in the plan as shown in Table II (p. 23). As may be seen by reference to this table, the dates of the successive applications were as follows: April 8, May 1, May 9, June 12, June 27, July 10, July 25, August 7, August 22, and September 4. The first date was just after the cluster buds had opened, exposing the blossom buds, but before the latter had opened; the second just after the petals had fallen, and the third application eight days later. The fourth date was about six weeks after the petals had fallen, the subsequent dates being at intervals of about two weeks. The object of the first three applications was to combine the treatment of apple scab with that of bitter-rot and to determine their effect upon the latter. As shown in Table II, one group of plots (Nos. 1 to 5) receiving three to nine applications had one or more of the late sprayings omitted. From another group (Plots 9 to 12) the early applications for scab were omitted. Plots 15, 16, 17, and 12, receiving four applications each, were designed to determine the period at which spraying gives the best results. Plots 7 and 8 combine early and late spraying, leaving an early midseason interval that proved in this case to be too long. Plot 6 was sprayed just before the trees bloomed, as soon as the blossoms were shed, and eight days later (the usual apple-scab treatment), and every two weeks from June 12 to September 4, receiving ten applications in all. It was intended that Plot 9 should be sprayed at intervals of two weeks, beginning June 12, making the treatment for this plot the same as No. 6, with the three early applications omitted; but the writer inadvertently overlooked the first date. Therefore, in order to avoid duplicating No. 10, two more applications were dropped out of No. 9 later in the season. The original scheme included Plots 13 and 14, which were to have received the last three and the last two applications, respectively; but when the time arrived for their treatment to begin the crop on them was already destroyed by the rot and they were therefore dropped.

Each plot consisted of but two trees. There were, then, in the experimental block fifteen treated plots of two trees each and five

untreated trees used as checks. By referring to the plat of the block (fig. 1) it will be seen that the checks (A, B, C, D, and E) were well scattered among the sprayed trees. Plot 1, at the lower left-hand corner, practically amounted to a check, as it received only the three early applications, and 62 per cent of the crop rotted. Check A is near the lower right-hand corner and B just below the center, while C and D are near the upper left-hand corner and E at the upper right-hand corner. Other trees were originally set aside as checks, but when it was found that bitter rot was developing abundantly on all of them some were sprayed in order to reduce the loss to the owner. Two trees to the plot might seem at first thought insufficient for determining the best results from the spraying, but the trees are quite large, yielding about 20 to 35 bushels each. Moreover, the plots are almost in duplicate, there being a difference usually of only one application in adjacent plots.

WEATHER CONDITIONS ATTENDING THE EXPERIMENT.

Better conditions for a severe test of spraying could scarcely be desired. As will be seen from the following weather table[a], there was an abundance of rain throughout the season and considerable high temperature. Beginning June 16 it rained every day except one until June 25, and during that period the temperature ranged high, reaching 89° F. on the 18th, 94° F. on the 19th, 90° F. on the 20th, 89° F. on the 21st, and 92° F. on the 22d. This combination of moisture and heat made an ideal infection period. The conditions during July were also favorable to bitter-rot. It rained every day during the first week and continued at intervals throughout the month. The temperature reached 94° F. on July 18, and was 92° F. on the preceding and the following day. The orchard was frequently enveloped in fog and the dews were usually very heavy. As a consequence all unsprayed trees showed bitter-rot early in the month, and by the end of the month the disease was well under way. This ideal bitter-rot weather continued through August, and before the end of that month the crop on all unsprayed trees was practically destroyed. The crops in the unsprayed orchards in the neighborhood were also badly affected, showing that the outbreak of bitter-rot was general in that region.

[a] No exact meteorological data being available for the immediate vicinity in which the experiments were conducted, data are given for Charlottesville, Va., the nearest point where permanent records are kept, a distance of about 25 miles from the site of the orchard used for the experiment. The weather conditions appeared to be similar in the two sections, and the table may be considered fairly representative of the conditions that prevailed in the orchard. The data are from the monthly reports of the Virginia Section of the Climate and Crop Service of the Weather Bureau.

TABLE I.—*Daily maximum and minimum temperatures and precipitation at Charlottesville, Va., for June, July, and August, 1905.*

Day of month.	June.			July.			August.		
	Temperature.		Precipitation.	Temperature.		Precipitation.	Temperature.		Precipitation.
	Maximum.	Minimum.		Maximum.	Minimum.		Maximum.	Minimum.	
	° F.	° F.	*Inches.*	° F.	° F.	*Inches.*	° F.	° F.	*Inches.*
1	68	52	0.03	72	64	0.48	80	61	.....
2	70	52	.04	87	63	.30	84	62	.....
3	75	54	.....	87	65	.05	84	64	.....
4	81	55	.....	89	66	2.70	83	.....	0.02
5	89	67	.....	82	66	.12	85	63	.....
6	92	71	.....	85	67	.33	91	67	.....
7	89	60	1.69	86	64	.62	90	64	.75
8	72	60	.....	87	70	.....	76	66	.02
9	77	63	.....	87	66	.....	84	67	1.67
10	81	64	.....	87	68	.....	85	69	.53
11	83	66	Trace.	85	69	.19	87	68	.11
12	86	69	.....	84	67	.82	88	71	.07
13	87	65	.....	77	68	.16	89	67	.01
14	86	65	.....	87	65	.63	82	66	.14
15	85	69	.....	89	65	.....	87	69	1.06
16	85	69	.18	87	68	.....	85	69	.....
17	86	69	.01	92	72	.....	70	59	.....
18	89	70	.05	94	74	.....	76	58	.....
19	94	67	.02	92	73	.....	75	58	.....
20	90	67	2.22	89	69	.70	82	59	.....
21	89	66	.70	85	70	.27	87	65	.....
22	72	69	.....	77	64	2.64	89	66	.....
23	75	69	.82	.....	.....	.01	88	66	.....
24	70	65	1.66	86	62	.....	88	63	.86
25	74	62	.04	80	63	.....	77	64	.36
26	77	68	.....	81	62	.....	77	63	.07
27	74	61	.....	81	61	.....	74	59	.....
28	78	57	.....	74	64	.09	77	50	.....
29	80	58	.....	85	64	.03	87	56	.....
30	82	62	.....	84	61	.....	89	70	.....
31	..	..	.....	77	65	.....	83	71	.....
Total	.....	.....	8.00	.....	.....	10.14	.....	.....	5.67
Mean	83.0	62.9	.....	84.5	66.2	.....	83.2	64.2	.....

RESULTS.

The results, as indicated below, are due entirely to spraying, no effort having been made to check the rot by any other measure. No mummies or cankers were removed, and the apples that became infected were allowed to remain on the trees until the crop was picked or until they dropped. Those that fell to the ground were left under the trees until picking time. The hands that worked in the orchard were specially instructed not to remove any of the diseased apples from the experimental block. The object was to test the value of Bordeaux mixture under the most adverse conditions, and all possible sources of infection were left undisturbed.

On July 10, specimens of bitter-rot apples, some of which are shown in Plate I, could be found here and there in the orchard, especially on unsprayed trees, and two weeks later (July 24) each tree was examined by walking around it and looking for infected fruits. The diseased fruits were counted, and a general idea of the condition on that date may be conveyed by the following summary of the notes made at that time:

On each of the checks (A to E) 100 to 250 affected fruits were

counted without climbing the trees, which probably means an infection of 10 to 15 per cent of the crop, since there must have been many diseased fruits unseen.

Plot 1 showed about 21 diseased fruits on each tree.

Plot 2 showed 5 diseased fruits on one tree and 6 on the other.

Plots 3, 4, and 5 showed 1 to 3 diseased fruits on each tree.

Plot 6 showed no rot.

Plots 7 and 8 showed 9 to 30 diseased fruits on each tree.

Plots 9 and 10 showed 7 to 18 diseased fruits on each tree.

Plot 11 showed 22 diseased fruits on one and 36 on the other tree.

Plot 12, which had not been sprayed, showed 112 diseased fruits on one and 150 on the other tree.

Plot 15 showed 25 affected fruits on one tree and 35 on the other.

Plot 16 showed 6 affected fruits on one tree and 10 on the other.

Plot 17 was apparently still free from bitter-rot.

The above is sufficient to indicate that in practically every tree there was an abundant supply of spores for a serious outbreak of the disease, and that wherever Bordeaux mixture was lacking the fungus became rampant.

It was almost impossible with the equipment used to spray the tops of most of the trees thoroughly, and later examinations showed that some bitter-rot occurred in the top of every tree. Every rain must have washed down an abundance of spores from diseased apples in the tops to fruits below.

In Table II the results from the two trees in each plot are combined, and the windfalls, both rotten and sound, are included. As a rule, half to three-fourths of the rotten fruit was on the ground at picking time. This was true of sprayed as well as unsprayed trees.

The crop of the experimental block was picked and sorted on September 19 to 23, inclusive, and the result from each tree kept separate. The fruit on the ground was picked up and classified into sound and rotten, and the fruit picked from the tree was likewise classified. Sound fruit constituted every apple free from bitter-rot, regardless of codling moth or scab. All fruits that were unmistakably affected with other rots, such as Sphæropsis, Penicillium, and Monilia, were discarded and not included in either class. As a rule, this did not exceed 3 per cent of the crop. Wherever there was any doubt, however, the trouble was charged to bitter-rot.

The final results of these experiments are shown in Table II, and it will be seen from this table that in every treated plot Bordeaux mixture had a beneficial effect regardless of the time of application, and that where the trees were properly sprayed the loss was less than 5 per cent of the crop, while the untreated trees suffered a total loss. It is rare that such results are obtained in the treatment of a plant disease. With the exception of leaf-curl of the peach, leaf-blight of the pear,

and possibly apple scab, these results would indicate that bitter-rot yields more completely to treatment than any other disease known to the writer. The infection period of bitter-rot being much longer, a greater number of applications are required to secure protection throughout the season, but it would seem that an apple coated with Bordeaux mixture would not be attacked by bitter-rot even under conditions otherwise most favorable to the fungus.

TABLE II.—*Scheme of spraying at Avon, Va., during the season of 1905, and its results.*

Plot numbers (2 trees to each plot).	Treatment with Bordeaux mixture (5-5-50 formula).									Picked Sept. 19 to 23.		
	Apr. 8.	May 1.	May 9.	June 12.	June 27	July 10.	July 25.	Aug. 7.	Aug. 22.	Sept. 4.	Sound fruit.	Rotten fruit.	Percentage of sound fruit.
											Bushels.	*Bushels.*	
1	"	"	"								18.50	30.25	37.9
2	"	"	"	"	"						47.50	22.50	67.8
3	"	"	"	"	"	"	"				56.00	2.00	96.5
4	"	"	"	"	"	"	"	"			54.00	1.75	96.8
5	"	"	"	"	"	"	"	"	"		32.75	1.15	96.6
6	"	"	"	"	"	"	"	"	"	"	68.50	.70	98.9
A	Check—one untreated tree.										.00	10.00	[a]00.0
7	"	"	"				"	"	"	"	56.50	14.00	80.1
8	"	"	"				"	"	"	"	7.00	6.50	51.8
9						"	"	"	"		28.50	6.00	82.6
B	Check—one untreated tree.										.00	17.00	[a]00.0
10						"	"	"	"	"	59.00	6.50	90.0
11							"	"	"	"	42.25	6.50	86.6
12								"	"	"	28.50	24.75	53.5
C	Check—one untreated tree.										.00	13.00	00.0
D	Check—one untreated tree.										.00	20.75	[a]00.0
15						"	"	"	"		52.25	5.25	90.8
16					"	"	"	"			52.50	3.75	93.3
17			"	"	"	"					40.00	5.00	88.8
E	Check—one untreated tree.										.25	16.25	1.5

[a] Of the check trees, A had 1 sound apple, B 6, and D 2, but the percentages were too small to show in the table.

In the first column on the left of this table the numbers of the sprayed plots are given in figures and the unsprayed trees are indicated by letters. The dates of the applications are given at the heads of succeeding columns, and the ditto marks after each plot number refer to these dates. For example, the marks after Plot No. 1 indicate that this plot was sprayed April 8, May 1, and May 9; while Plot No. 12 was sprayed July 25, August 7 and 22, and September 4. The three columns on the right show the results in bushels of sound fruit, bushels of rotten fruit, and percentage of sound fruit for each plot, as determined when the crop was picked, September 19 to 23. The check plots are placed in the table about as they occurred in the orchard, Plot A being located near the lower side, while Plot E is at the upper side.

Plot 1, as will be seen from the table, received but three applications (those usually given in the treatment of apple scab), on April 8, May 1, and May 9, with the result that only 37.9 per cent of the fruit was saved from bitter-rot, showing that the treatment was stopped too early. (Pl. V, fig. 1.)

Plot 2 received, in addition to these three treatments, one on June 12, after an interval of 33 days, and a fifth application on June 27, with the result that 67.8 per cent of the crop was saved.

Plot 3 received, in addition to the foregoing treatments, one application on July 10 and another on July 25, making seven in all, with the result that 96.5 per cent of the crop was saved. (See Pl. III, fig. 1.)

Plot 4 received eight treatments, the dates being the same as in Plot 3, with an additional application on August 7. The percentage of sound fruit was 96.8.

Plot 5 received an additional treatment August 22, making nine applications in all, with the saving of 96.6 per cent of the crop.

Plot 6 was sprayed as in Plot 5, with an additional treatment on September 4, thus receiving an application on every spraying date, or a total of ten, the largest number given any plot in the experiment. The result was a saving of 98.9 per cent of the crop. (Pl. IV, fig. 1.)

Check A, which consisted of one untreated tree, yielded only one sound fruit and 10 bushels of rotten fruit. (Pl. III, fig. 2, and Pl. VII.)

Plot 7 received the first three applications, namely, on April 8, May 1, and May 9; and the last four, namely, on July 25, August 7, August 22, and September 4, leaving an interval of about two months and a half during which the trees were not sprayed. This interval was too long, as indicated by the yield of only 80.1 per cent of sound fruit.

Plot 8 was sprayed on the same dates as Plot 7, with the omission of the application on July 25, so that the interval during which the trees were not sprayed was about three months, resulting in a saving of only 51.7 per cent of the crop.

Plot 9 received applications 5, 6, 7, and 9, namely, on June 27, July 10, July 25, and August 22, 82.6 per cent of the crop being saved.

Check B, consisting of one untreated tree, yielded 17 bushels of rotten fruit and only six sound apples.

Plot 10 received applications 5 to 10, namely, on June 27, July 10, July 25, August 7, August 22, and September 4, 90 per cent of the fruit being saved.

Plot 11 differed from Plot 10 in that the treatment of June 27 was omitted. As a result of these five applications, 86.6 per cent of the crop was saved.

Plot 12 received one application less than Plot 11, the first treatment occurring July 25. Only 53.5 per cent of the crop was saved. (Pl. V, fig. 2.)

Check C, which consisted of one unsprayed tree, had 13 bushels of rotten fruit and no sound fruit, the entire crop having been destroyed.

Check D, one untreated tree, yielded 20¾ bushels of rotten fruit and only two sound apples. (Pl. IV, fig. 2.)

Plot 15 was sprayed on July 10, July 25, August 7, and August 22, and yielded 90.8 per cent of sound fruit.

Plot 16 received the same number of treatments as Plot 15, but the spraying was begun and ended two weeks earlier, the first application being made on June 27 and the last August 7. As a result 93.3 per cent of sound fruit was obtained. (Pl. VI, fig. 2.)

Plot 17 also received four applications at intervals of two weeks, but the treatment was begun two weeks earlier than in Plot 16, the spraying dates being June 12, June 27, July 10, and July 25. The yield of sound fruit was 88.8 per cent.

Check E, one untreated tree, yielded one fourth bushel of sound fruit and 16¼ bushels of rotten fruit, the percentage of sound fruit being 1.5.

BENEFICIAL EFFECTS OF SPRAYING.

In analyzing the results as shown in Table II it is not difficult to conclude that in Plots 1 and 2 spraying was stopped too early, that in Plot 12 spraying was begun too late, and that in Plots 7 and 8 the interval between the early and late applications was too long. From Plots 3 to 6, as compared with Plots 1, 2, 7, 8, and 12, and the checks, it is also plainly evident that bitter-rot can be completely controlled by coating the fruit with Bordeaux mixture before infection takes place and keeping it thoroughly coated throughout the season. Moreover, Plots 10, 11, 15, 16, and 17 seem to indicate that, so far as bitter-rot is concerned, spraying before the trees bloom and within a month after the blooming period is not absolutely necessary. It is clearly seen by comparison, however, that the three early applications (April 8, May 1, and May 9) had a decidedly beneficial effect in all the plots that received them. Compare Plot 1, which received only these three applications and yielded 37.9 per cent of sound fruit, with the unsprayed trees, A to E, which yielded practically no sound fruit. Plot 12, which received four late applications (July 25, August 7, August 22, and September 4), gave only 53.5 per cent of sound fruit, while Plot 7, which had the same treatment and in addition the three early applications, gave 80.1 per cent of sound fruit. The three early applications thoroughly coated the branches and leaves, as well as the very young fruit, and it is probable that protection from infection was prolonged by the action of the rains in washing the copper from the leaves to the fruits. Of the several plots receiving only four applications each, No. 16, which received its first application on June 27, gave the best results, yielding 93.3 per cent of sound fruit. However, Plot 17, which had its first application two weeks earlier and yielded 88.8 per cent of sound fruit, would perhaps have shown up as well as No. 16 but for the fact that the upper side of one of the trees could not be properly reached with the spray. It appears, therefore, from this

group of plots that the ideal treatment would have been five applications at intervals of two weeks, beginning June 12. Comparing Nos. 12 and 15, it is further noted that a delay of two weeks—from July 10, the date the first application was given No. 15, to July 25, the date treatment began on No. 12—made a difference of 37.3 per cent in favor of the earlier applications, representing the difference between success and failure.

Considering the series of Plots 2 to 8, which combine the three early applications for scab and the later applications for bitter-rot, No. 3 is the most satisfactory. This plot was sprayed seven times, namely, on April 8, May 1, and May 9 for scab, and on June 12, June 27, July 10, and July 25 for bitter-rot, and the result was 56 bushels of sound fruit and only 2 bushels of rotten fruit from the two trees, or 96.5 per cent of sound fruit. Plots 4, 5, and 6 each had a slightly larger percentage of sound fruit, but scarcely enough to pay for the additional spraying which they received. However, the bitter-rot fungus is so influenced by weather conditions that it is scarcely safe to follow No. 3 and stop spraying as early as July 25. The treatment (eight applications) given Plot 4 would doubtless be necessary in some seasons to prevent both scab and bitter-rot. The results obtained in Plots 15, 16, and 17 seem to indicate that four applications at intervals of two weeks, beginning June 12, June 27, or even as late as July 10, would be the most satisfactory treatment, when the cost of spraying is considered, but as a rule it pays to give three or four treatments earlier in the season for apple scab, leaf-spot, and codling moth, and, therefore, these early spring applications, combined with the early summer applications, undoubtedly give the most satisfactory results.

The lesson to be learned from Plots 7 and 8, as compared with Plot 6, is that the omission of the June and July applications is almost fatal to the crop. Comparing Plots 7 and 8, it is seen that the one extra application given to the former on July 25 resulted in a saving of 28.4 per cent over the latter. Again, comparing Plots 11 and 12, it is seen that one extra application given to the former on July 10 resulted in a saving of 33.1 per cent over the latter. These results emphasize the importance of spraying at the right time, and in order to be sure of covering the proper time the applications must be spread out over a long period.

EFFECT OF THE TREATMENT ON OTHER DISEASES.

Scab.— It is already well known that apple scab is easily controlled by spraying with Bordeaux mixture. This disease was completely prevented on the trees in the experimental plots receiving the three early applications, namely, first, just before the trees bloomed; second, as soon as the blossoms were shed, and third, eight days later. Some scab appeared on the trees not so treated, but this variety of apple

(Yellow Newtown) does not usually suffer from scab so much as some other varieties. The same treatment was given a block of Winesaps, with the result that the fruit at picking time showed practically no scab, while the three unsprayed trees left as checks had 80 per cent of the crop affected.

Leaf-spot.—The disease known as leaf-spot, which also yields readily to treatment, is very common in Virginia, causing considerable damage by defoliating the trees, and certain varieties of apples require treatment for this disease alone. Trees sprayed as early as June 12 held their foliage in fine condition until after the crop was harvested. The three early applications did not entirely prevent the leaf-spot disease, and the best results were obtained when the treatment was continued until July 25 or later. Winesaps that were sprayed as soon as the blossoms were shed, May 1, and at intervals of two weeks until three applications had been made, lost practically no foliage from leaf-spot. Also two trees sprayed on May 18, about three weeks after the blooming period, and on June 12 kept their foliage in perfect condition throughout the season. On the other hand three unsprayed Winesaps in the same orchard lost 50 to 75 per cent of their leaves by August 7, and most of those remaining on the trees at that date were affected. The unsprayed Yellow Newtowns, however, did not suffer half so much. The trees thus defoliated were not able to properly mature the fruit, which at picking time was perceptibly smaller than that of sprayed trees. In some cases the sprayed fruit was as much as one-fourth larger than that on the unsprayed trees.

Sooty-blotch.—Sooty-blotch also yielded very readily to treatment, the fruit on all the sprayed trees being clean, while a portion of the untreated fruit was more or less "clouded." The three early applications for scab appeared to be sufficient to control this fungus, though in severe cases two applications in July would no doubt be necessary to prevent the disease.

INJURIOUS EFFECTS OF THE TREATMENT.

Russeting.—The fruit on all of the trees that received the three early applications in the bitter-rot experiment on the Yellow Newtown apples developed russet spots or blotches due to the action of the copper. These blotches sometimes covered half of the apple, dwarfing the affected side. Usually, however, the spots were small and very irregular in shape, detracting little from the appearance of the apple. Fruits that did not receive these early sprayings were not affected, and the trouble seems to have resulted entirely from the two applications made to the young fruit on May 1 and 9. About 50 per cent of the fruit sprayed on these dates showed some russet spots, but the disfiguration was apparently not sufficient to affect its market value materially. When russeting is feared it might be advisable to use less bluestone and a greater quantity of lime in the preparation of

Bordeaux mixture for application to the very young fruit. The mixture used in spraying stone fruits (3 pounds of bluestone and 9 pounds of lime to 50 gallons of water) is suggested.

Coating of Bordeaux mixture.—The fruit from Plot 3, which received its last application on July 25, was practically free from Bordeaux mixture at picking time, September 19 to 23, the coating having weathered away. (Pl. III, fig. 1.)

The fruit from Plot 4, which received its last application on August 7, showed considerable Bordeaux mixture at picking time, but not sufficient to attract special notice.

The fruit from Plots 5 and 6, and, in fact, from all of the plots sprayed after August 7, was thoroughly coated with Bordeaux mixture at picking time. (See Pl. IV, fig. 1; Pl. V, fig. 2, and Pl. VI, fig. 2.)

The presence of Bordeaux mixture on the fruit when packed is certainly objectionable, but it was found that in picking, grading, and barreling the apples most of it was rubbed off. The crop from the sprayed trees, both in the experimental block and in Mr. Goodwin's main orchard, was sold at the highest price paid for Yellow Newtown apples in that section the past season, and the purchaser raised no objection to the coating of Bordeaux mixture and did not require the fruit to be wiped.

COMMERCIAL OPERATIONS.

The Bureau of Plant Industry furnished a number of its correspondents with suggestions for the treatment of bitter-rot, and during the past season the writer visited a few of the orchards that were sprayed in accordance with these suggestions, as well as others that had not been properly treated. In every case where Bordeaux mixture was applied at the proper time good results were secured. Even poor spraying had a decidedly beneficial effect. Owing to the steepness of the land or to some other obstacle, there were always some trees left untreated or but partially sprayed, thus affording ample checks with which to compare the treated trees. In most cases the results were very striking, showing almost a perfect crop on the sprayed trees and a loss of 75 to 100 per cent of the crop on the unsprayed trees. More striking still is the fact that where only one side of a tree was sprayed the crop on that side matured in perfect condition, while the crop on the opposite side was destroyed by bitter-rot. The writer observed this in a number of instances where a fence or a steep hillside admitted of the treatment of only one side of the trees.

RESULTS IN SEVERAL ORCHARDS.

Aside from the trees used in the experiment, Mr. W. H. Goodwin, of Avon, Va., sprayed the larger portion of his orchard under the

directions of the Bureau of Plant Industry, and the writer was able to see the work in progress from time to time and to note the results.

The treatment consisted of eight applications of Bordeaux mixture, corresponding very closely to Plot 5 of the experiment, with the omission of the fourth application (June 12), and the results appeared to be equally as good as those obtained in that plot (96.6 per cent of sound fruit). The commercial spraying was done with the same outfit and the same men employed in the experimental work and usually began the day after that work was completed.

The results of this treatment are set forth very clearly in a letter from Mr. Goodwin to the writer under date of November 3, 1905, as follows:

> Replying to your favor of November 1, I have to say that in accordance with your directions I sprayed the major portion of my orchard of Albemarle Pippins eight times, beginning the applications on the following dates: April 9, May 2, May 10, June 28, July 11, July 26, August 10, and August 26. The portion of the orchard thus sprayed had practically no bitter-rot—perhaps not more than 2 per cent. On the other hand, the fruit on some 250 trees which could not be sprayed owing to steepness of land and lack of water was almost entirely lost from the bitter-rot. The crop on this portion of the orchard was estimated at about 800 barrels; but at picking time there were no No. 1's, and only 134 barrels of No. 2's (nearly all of which were more or less specked) were gathered.
>
> I am fully convinced that the bitter-rot may be almost entirely prevented by proper spraying with Bordeaux mixture, and in my opinion the establishment of this fact has reclaimed the pippin industry in Virginia. The last two crops were entirely lost from bitter-rot, whereas the crop the present year was saved by spraying. My trees are from 12 to 23 years old, and averaged about 3 barrels per tree. The trees were very thoroughly sprayed, costing for the eight applications about 30 cents per tree.

The orchard referred to was examined from time to time during the season, and on July 10 a few apples affected with bitter-rot were found, perhaps an average of less than one to each tree in the sprayed portion, and slightly more on unsprayed trees. By August 21, 75 per cent of the crop on most of the unsprayed trees was destroyed, and the fruit out of reach of the spray on the topmost branches of some of the tallest trees in the sprayed portion was badly affected, while all trees properly treated showed practically no rot. On a certain steep hillside the end tree in each row could be sprayed only on one side, resulting in a full crop of sound fruit on the sprayed half of the tree, while practically all of the fruit rotted on the other half.

Mr. William B. MacGregor, of Avon, Va., whose orchard is adjacent to the Goodwin orchard, sprayed his trees very thoroughly and persistently throughout the season, and was rewarded with a magnificent crop of almost perfect fruit. The writer had opportunities to visit this orchard while the spraying work was being done, and also at picking time. The course of treatment and summary of results are

given in a letter from Mr. MacGregor, dated November 10, 1905, as follows:

In reply to yours of October 31, I do not know the exact dates of spraying. In the part where the most spraying was done the first application was made about April 15, followed by others on May 7, June 1, and at intervals of from 13 to 17 days thereafter until September 1, making nine applications in all. Practically no rot appeared on this part. On trees not sprayed till June 1 the rot might be 3 per cent, but not more. On three trees not sprayed August 1, but which received all the other applications, no difference was noted. Applications must be thorough. Some of our trees had only a few apples, and to save time we tried to spray them only in July and August. Result, 25 per cent bitter-rot at least.

The orchard of Messrs. J. W. Rodes and Sons is located in the Rockfish Valley, about eighteen miles from Afton, Va. Mr. Rodes corresponded with the Bureau of Plant Industry concerning the treatment of the bitter-rot disease, and on July 26 the writer visited the orchard. The appearance of the trees indicated that they had been thoroughly sprayed with Bordeaux mixture, and on that date Mr. Rodes was spraying the tops of his tallest trees with an extra long extension rod, made by joining two rods of his outfit into one. He realized the importance of reaching every fruit with the mixture. With the exception of an occasional diseased fruit the sprayed portion of the crop throughout the orchard was free from bitter-rot. However, on one side of the orchard a fence interfered with the spraying, and about one-third of the crop on each of several trees could not be easily reached. In every such case the unsprayed section of the tree showed a serious outbreak of bitter-rot. A letter from Mr. S. T. Rodes, dated at Bryant, Va., November 3, 1905, and giving a statement of the treatment and the results obtained follows:

Yours of October 31 to hand and contents noted. In reply will say we sprayed our orchard of 275 Albemarle Pippins six times for bitter-rot, starting on the dates given below and finishing as soon as possible. [Mr. Rodes then names the dates of commencing six successive sprayings, as follows: June 15, July 3, 15, and 31, August 17 and 30.]

Where we could get at the trees and made the six applications there was no bitter-rot worth mentioning—scarcely any at all. Some trees that we could not spray on both sides on account of the fence showed quite a difference, the side sprayed having nice, clean apples, clear from cloud and rot, the fruit on the other side, unsprayed, being clouded and nearly all infested with the bitter-rot.

Two years ago I believe the trees bore as many apples as they did this year. We did not spray them, however, and gathered only 56 barrels. From the same trees this year, but well sprayed inside and out, we gathered 1,142 barrels of No. 1 Pippins.

In unsprayed and poorly sprayed orchards in the Rockfish Valley bitter-rot was exceedingly bad, and there can be no doubt that the freedom from the disease in the sprayed orchards was due entirely to the treatment.

PREPARATION OF BORDEAUX MIXTURE.

The Bordeaux mixture used in the experiments was prepared according to the following formula:

5 pounds of copper sulphate (bluestone).
5 pounds of fresh stone lime.
50 gallons of water.

For small lots dissolve the bluestone in 25 gallons of water, and in a separate vessel slake the lime by sprinkling it with water until a thick paste is formed, and then dilute it to 25 gallons. Then pour the two solutions together through a strainer into the spray tank or other receptacle, a bucketful of each at the same time. When thoroughly stirred, the mixture is ready for application.

For extensive spraying, stock solutions should be prepared. Weigh out 50 pounds of bluestone into a coarse bag and suspend it in a 50-gallon barrel of water near the top. The bluestone thus suspended will usually dissolve within twenty-four hours, and the barrel should then be filled to the 50-gallon mark. Each gallon of this solution contains 1 pound of bluestone. Likewise 50 pounds of lime is placed in a barrel and slaked by slowly pouring water over it. While slaking keep it thoroughly stirred with a shovel, and continue to add water enough to keep it from burning, but the mass should not be submerged. When thoroughly slaked, dilute to 50 gallons. Each gallon will then contain the equivalent of 1 pound of lime, provided it is thoroughly agitated. Therefore, in order to make up 50 gallons of the mixture take 5 gallons of the bluestone solution and 5 gallons of the lime water. To prepare 200 gallons of the mixture for a spray tank of that capacity 20 gallons of each constituent would be required, but it should be remembered that these concentrated solutions should be diluted before pouring them together.

In order to save so much dipping, the mixing should be done on an elevated platform, such as shown in Plate VIII, figure 1. The platform shown in this illustration was constructed at the writer's suggestion by Mr. W. H. Goodwin for use in the bitter-rot experiments, as well as for his commercial work, and is about 2 feet higher than the top of the spray tank on the wagon. The stock solutions are kept in 50-gallon barrels on the rear of the platform, and the two dilution tanks, holding 100 gallons each, are placed at the front edge of the platform. The bluestone solution is placed in one of these tanks and the lime water in the other. Then each is filled with water up to the 50, 75, or 100 gallon mark, as desired. A molasses gate (or faucet) is fixed in a hole bored near the bottom of each tank, and this connects with an open trough leading to the strainer in the spray tank. Each of these gates is opened at the same time, and thus the two solutions are allowed to run together into the spray tank. In this case the

water came from a spring about 100 yards above the platform, and was conducted into the barrels and tanks on the platform through open troughs. Where the convenience of an elevated spring is lacking, the water may be pumped up by hand, windmill, or engine.

METHOD OF APPLYING BORDEAUX MIXTURE.

The following account of the method of applying the Bordeaux mixture in the experiments of the Bureau of Plant Industry may perhaps serve as a guide to fruit growers in treating their orchards. One can not emphasize too strongly the necessity of reaching every part of the tree with the spray and coating the fruits on all sides.

The spraying was done with a specially constructed pump and a tank of 200 gallons capacity. The pump is fitted with two sections of ½-inch hose, each 25 feet long, with a 14-foot bamboo extension rod attached and double Vermorel nozzles. This outfit is seen in operation in Plate VIII, figure 2. When convenient two trees were sprayed at the same time, and the operators were thus kept out of each other's way. In spraying the tall trees the operator had to stand on the spray tank or climb the tree. Where the conditions will admit, an elevated platform built on top of the spray tank should be used for this purpose, but in the case here mentioned the land was too steep.

In making the first application great care was taken to coat the bark thoroughly from the ground to the tips of the twigs, but later applications were aimed at the fruit and foliage only. Nozzles with small apertures were used and the pressure was kept as high as one could maintain it with a hand pump. This produced a fine mist, and the attempt was made to spray the tree so thoroughly as to envelop every apple in this mist. So far as practicable, the trees were sprayed from every direction so as to hit every apple all over. When it could be avoided, the trees were not left dripping, the aim being to pepper the fruit and leaves thoroughly without producing drops large enough to run off. Good spraying does not consist in drenching the tree.

For extensive operations some form of power sprayer should be used where the conditions are suitable. Gasoline sprayers are perhaps the most promising, but in some instances they have been disappointing.

CONCLUSIONS AND RECOMMENDATIONS.

Summarizing the results obtained, and considering the fact that the experiments were made during a season unusually favorable to bitter-rot, the following conclusions may be drawn:

1. Bitter-rot can be completely controlled by proper applications of Bordeaux mixture, 93.3 to 98.9 per cent of sound fruit having been saved by such treatment in these experiments, while the checks rotted completely.

2. Four applications, when made just at the right time, are sufficient to control the disease satisfactorily, but in order to be sure of covering the infection periods one or two additional applications may be necessary.

3. The applications should be made at intervals of two weeks, beginning about six weeks after the trees bloom.

4. It is necessary to spray the trees thoroughly, coating the fruit on all sides with fine mist-like applications.

5. Other diseases, such as scab, leaf-spot, and sooty-blotch, may be controlled in connection with the treatment of bitter-rot.

For the treatment of bitter-rot alone, spray the trees thoroughly with Bordeaux mixture at intervals of two weeks until five applications have been made, beginning not later than forty days after the petals have fallen (in Virginia usually about June 10 to 15).

For the combined treatment of apple scab and bitter-rot, spray the trees with Bordeaux mixture (1) just before they bloom (but after the cluster buds have opened and exposed the flower buds); (2) as soon as the petals fall; (3) a week or ten days later; and (4) about forty to fifty days after the shedding of the petals, and at intervals of two weeks thereafter until, in all, seven or eight applications have been made.

It is true, of course, that the number of applications required and the dates on which they should be made depend to a considerable extent upon the season, but the treatment should always begin before the infection period, which may occur as early as forty to fifty days after the fruit has set (in Virginia, perhaps by the middle of June in some seasons).

In a dry or cool season the intervals between the later sprayings may be lengthened, thus reducing the number of applications required, provided the fruit is first thoroughly coated, which will necessitate at least two applications.

On the other hand, in a hot, humid season it will probably be necessary to shorten the intervals and increase the total number of applications.

Should, for any reason, the treatment be delayed until after it is discovered that infection has taken place, the trees should be thoroughly sprayed twice in rapid succession with an interval of only a few days, in order to coat the fruit thoroughly as quickly as possible. With one application alone it is difficult to coat the fruits sufficiently to protect against bitter-rot, and the second application, which adheres better than the first on account of the presence of the previous coating and also reaches parts of the fruit not touched before, is necessary for thorough protection.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Three apples affected with bitter-rot and three mummies which presumably furnished the infection. The twigs with these fruits and mummies attached were cut from one of the unsprayed trees in the experimental orchard on July 10, and the photograph was made two days later.

PLATE II. The microscopic characters of the bitter-rot fungus (*Glomerella rufomaculans* (Berk.) Spaulding & von Schrenk): *1.*—Five asci, each containing eight ascospores; also one probably immature ascus. × 900. *2.*—A group of free ascospores. × 900. *3.*—A group of ascospores germinating in a drop of water. × 900. *4.*—Spore-bearing hyphæ springing from a mycelium growing in nutrient agar: *a*, the mycelium giving rise to the fertile hyphæ; *b*, a group of conidia, or summer spores, newly born. × 600. *5.*—A group of germinating conidia. × 740. *6.*—A section through a pustule showing the ruptured skin of the apple, the spore-bearing hyphæ, and the free conidia. × 200.

PLATE III. Fig. 1.—The crop picked from one tree of Plot 3, showing 33¼ bushels of sound fruit on the left and 1¾ bushels of rotten fruit on the right. Fig. 2.—Fruit from an untreated tree (Check A). The only sound apple from the tree is shown on top of the basket.

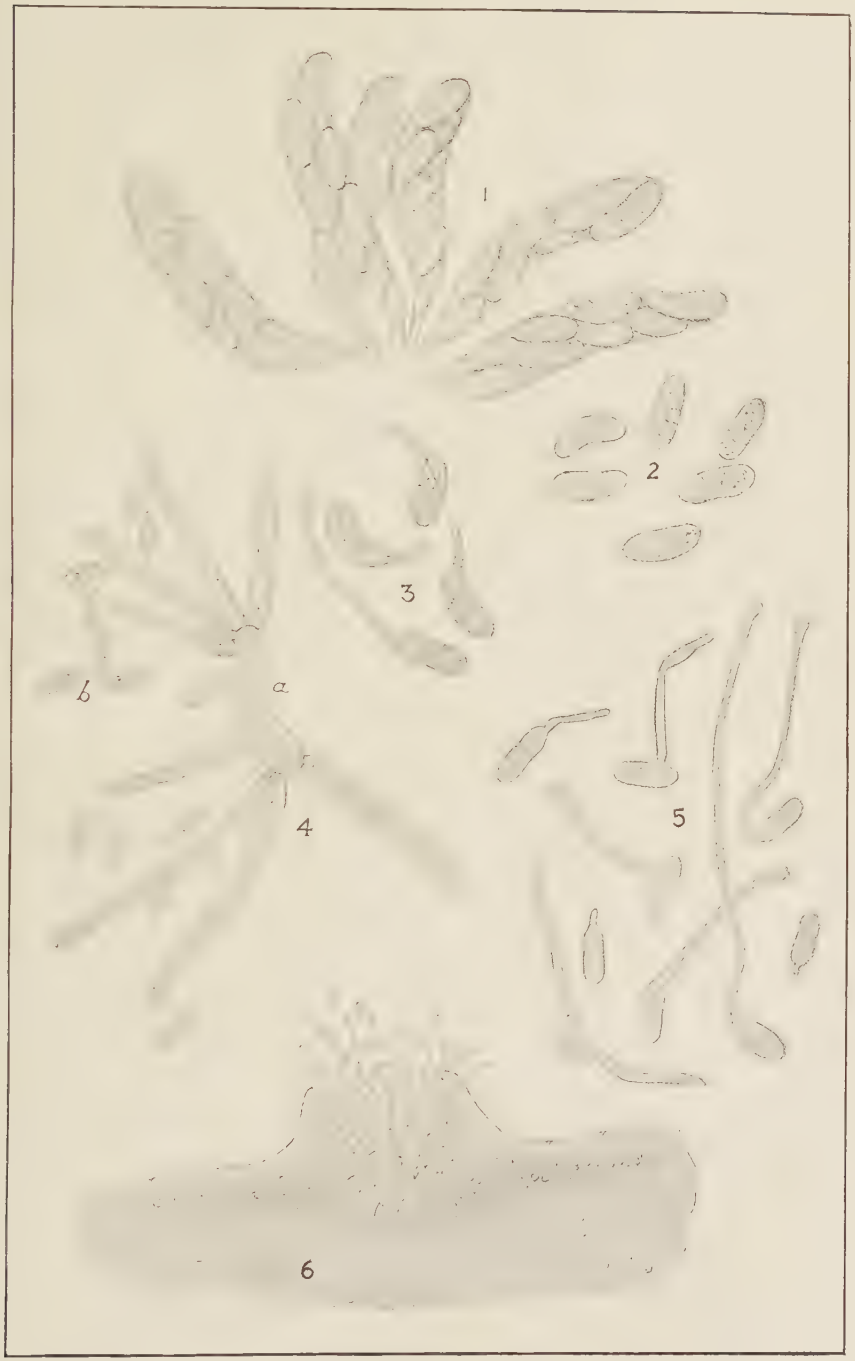
PLATE IV. Fig. 1.—Crop picked from one of the trees in Plot 6, showing 39 bushels of sound fruit and less than a peck of rotten fruit in the half-bushel measure on top of the pile. The fruit still shows a coating of Bordeaux mixture. Fig. 2.—The crop from an unsprayed tree (Check D), showing only two sound apples, which are placed on a board on top of the heap of rotten fruit.

PLATE V. Fig. 1.—Fruit from one of the trees in Plot 1, showing 13¼ bushels of bitter-rot apples on the right, and 10 bushels of sound apples on the left; treatment too early for best results. Fig. 2.—The fruit from Plot 12, showing 12 bushels of sound apples on the right, and 12¾ bushels of rotten fruit on the left; treatment too late to save the crop.

PLATE VI. Fig. 1.—A yellow Newtown apple badly affected with bitter-rot, and another recently mummified by the fungus. The specimen designated *A* shows a typical case of bitter-rot on a Yellow Newtown apple. The fruit was taken from the tree in this condition. The apple marked *B* has been recently mummified by bitter-rot, the entire fruit having become involved in decay. Fig. 2.—Apples harvested from one tree in Plot 16, showing 28½ bushels of sound fruit above and to the left, and 1½ bushels of rotten fruit in and near the baskets.

PLATE VII. An unsprayed tree (Check A) with most of its crop on the ground at picking time, illustrating the destructive work of the bitter-rot.

PLATE VIII. Fig. 1.—The platform and equipment used in preparing Bordeaux mixture; also showing the spray tank receiving a supply of Bordeaux mixture. Fig. 2.—The spraying outfit in operation.



THE MICROSCOPIC CHARACTERS OF THE BITTER-ROT FUNGUS IN VARIOUS STAGES.

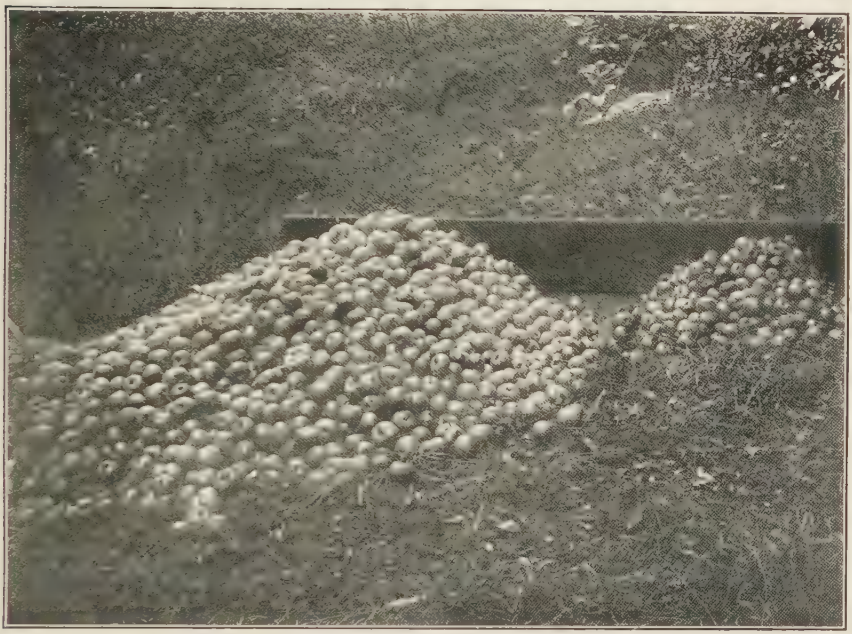


FIG. 1.—CROP OF APPLES FROM ONE TREE OF PLOT 3, SPRAYED SEVEN TIMES.

FIG. 2.—CROP FROM AN UNSPRAYED TREE (CHECK A).

FIG. 1.—APPLES HARVESTED FROM ONE TREE OF PLOT 6, SPRAYED TEN TIMES.

FIG. 2.—CROP FROM AN UNSPRAYED TREE (CHECK D).

FIG. 1.—APPLES HARVESTED FROM ONE TREE OF PLOT 1, SPRAYED THREE TIMES; APPLICATIONS MADE TOO EARLY.

FIG. 2.—CROP OF APPLES FROM ONE TREE OF PLOT 12, SPRAYED FOUR TIMES; APPLICATIONS MADE TOO LATE.

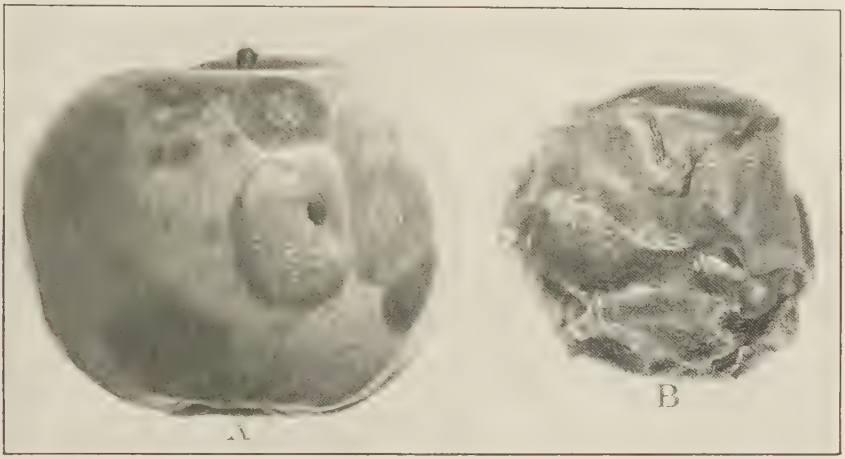


FIG. 1.—A YELLOW NEWTOWN APPLE (A) BADLY AFFECTED WITH BITTER-ROT, AND ANOTHER (B) RECENTLY MUMMIFIED BY THE FUNGUS.

FIG. 2.—THE CROP FROM ONE TREE OF PLOT 16, SPRAYED FOUR TIMES AT THE RIGHT PERIOD.

AN UNTREATED APPLE TREE (CHECK A), WITH THE BULK OF ITS CROP ON THE GROUND AT PICKING TIME.

FIG. 1.—PLATFORM AND EQUIPMENT FOR MAKING BORDEAUX MIXTURE.

FIG. 2.—THE SPRAYING OUTFIT IN OPERATION.

[Continued from page 2 of cover.]

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